RTCA SC- 186/WG-6 (Working Group On DO-242A MASPS)

Meeting #6, Seattle WA

Draft Text for DO-242A

Relating to “NIC/NAC/SIL” and SV and MS Report Content

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SUMMARY
This paper is offers draft text for DO-242A in support of the “NIC/NAC/SIL” proposals outlined in 242A-WP-6-03, which showed corresponding draft changes presented to WG-3 for the 1090 MHz data link MOPS, DO-260A. This paper is a revision of an earlier paper, 242A-WP-4-02. **[The text is color-coded: black for original text from DO-242, blue for changes to that text that were made in the previous draft (242A-WP-4-02), or red for changes made in the current draft (242A-WP-6-11).]**

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2.1 General Requirements

2.1.1 General Performance

2.1.1.1 Consistent Quantization of Data

When the full resolution of available aircraft data cannot be accommodated within an ADS-B message, a common quantization algorithm shall (R2.1) be used to ensure consistent performance across different implementations. To minimize uncertainty, a standard algorithm for rounding/truncation is required for all parameters. For example, if one system rounds altitude to the nearest 100 feet and another truncates, the same measured altitude could be reported as different values.

2.1.1.2 ADS-B Report Characteristics

The output of ADS-B shall (R2.2) be standardized so that it can be translated without compromising accuracy. The ADS-B reports should support surface and airborne applications anywhere around the globe and should support chock-to-chock operations without the need for pilot adjustments or calibration.

2.1.1.3 Expandability

Applications envisioned for using the information provided by ADS-B are not fully developed. In addition, the potential for future applications to need information from an ADS-B is considered fairly high. Therefore the ADS-B system defined to meet the requirement in this MASPS needs to be flexible and expandable. Any broadcast technique should have excess capacity to accommodate increases and changes in message structure, message length, message type and update rates.

<u>Note</u>:*The update rate is the effective received update rate as measured at the receiving end system application (e.g., the automation system interface by ADS ground processing), not the transmission rate of the ADS-B system.*

This MASPS identifies different report parameters with different update rates. In some cases the resolution of the parameters may be different depending on the intended use. Ideally, the system should be designed so that message types, message structures, and report update rates can be changed and adapted by system upgrades.

2.1.1.4 Time of Applicability

The time of applicability of ADS-B reports indicates the time at which the reported values were valid. Time of applicability shall (R2.3) be provided in all reports. Requirements on the accuracy of the time of applicability are addressed in Section 3.

2.1.2 Information Transfer Requirements

The ADS-B system shall (R2.4) be capable of transmitting messages containing the information specified in the following subsections. This MASPS does not specify a particular message structure or encoding technique. The information specified in the following subsections can be sent in one or more messages in order to meet the report update requirements specified in Section 3.

2.1.2.1 Identification

The basic identification information to be conveyed by ADS-B shall (R2.5) include the following elements:

- Call sign
- Address
- Category

The ADS-B system design shall (R2.6) accommodate a means to ensure anonymity whenever pilots elect to operate under flight rules permitting an anonymous mode. (Most on-IFR flight operations do not require one to fully disclose either the A/V call sign or address. This feature is provided to encourage voluntary equipage and operation of ADS-B by ensuring that ADS-B messages will not be traceable to an aircraft if the operator requires anonymity.)

2.1.2.1.1 Call Sign

ADS-B shall (R2.7) be able to convey an aircraft call sign of up to 8 alphanumeric characters in length [<substitute reference to ICAO, *Annex 10 to the Convention on International Civil Aviation,* Volume IV, Chapter 3, §3.1.2.9.1.2>]. For aircraft/vehicles not receiving ATS services and military aircraft the call sign is not required.

Note: The call sign of an ADS-B participant is reported in the Mode Status (MS) report (section 3.4.3.2 below).

2.1.2.1.2 Address

The ADS-B system design shall (R2.8) include a means (e.g., an address) to 1, correlate all ADS-B messages transmitted from the A/V and 2, differentiate it from other A/Vs in the operational domain.

Those aircraft requesting ATC services will be required in some jurisdictions to use the same 24 bit address for all CNS systems. Aircraft with Mode-S transponders using an ICAO 24 bit address shall (R2.9) use the same 24 bit address for ADS-B. All aircraft/vehicle addresses shall (R2.10) be unique within the operational domain(s) applicable.

Notes:

1. *For example, all surface vehicles for a given airport need to have unique addresses only within range of the airport; vehicle addresses may be reused at other airports.*
2. *Correlation of ADS-B messages with transponder codes will facilitate the integration of radar and ADS-B information on the same A/V during transition.*
3. *A participant's address is included as part of all reports about that participant (SV, MS, and the various types of OC reports).*

2.1.2.1.3 Participant Category

Participant category (Aircraft/vehicle category, as defined by ICAO[6]), shall (R2.11) be one of the following:

1. Light aircraft - 7,000 kgs (15,500 lbs) or less
2. Reserved
3. Medium aircraft - more than 7,000 kgs and less than 136,000 kgs (300,000 lbs)
4. Reserved
5. Heavy aircraft 136,000 kgs or more
6. Highly maneuverable (> 5g acceleration capability) and high speed (> 400 knots cruise)
7. Reserved
8. Reserved
9. Reserved
10. Rotorcraft
11. Glider/Sailplane
12. Lighter-than-air
13. Unmanned Aerial vehicle
14. Space/Transatmospheric vehicle
15. Ultralight/Hangglider/Paraglider
16. Parachutist/Skydiver
17. Reserved
18. Reserved
19. Reserved
20. Surface Vehicle - emergency vehicle
21. Surface Vehicle - service vehicle
22. Fixed ground or tethered obstruction
23. Reserved
24. Reserved

Note 1: *2, 4, 7-9, 17-19, 23 and 24 reserved for future assignment.*

Note 2: *A participant's category is reported in the Mode Status (MS) report (section 3.4.3.2 below).*

2.1.2.2 State Vector

The reported state vector for an A/V includes the three-dimensional position and velocity referenced to an accepted world-wide reference system.

The accuracy of the state vector information affects its utility for surveillance applications. Accuracy requirements for surveillance applications using ADS-B are based on the uncertainty in each state vector element that is required to support a given application.

Note: The accuracy and integrity of the position and velocity elements of the state vector are communicated in the Mode Status report. See the descriptions of Navigation Integrity Category (NIC), Navigation Accuracy Categories for Position and Velocity (NAC_P and NAC_V), and Surveillance Integrity Level (SIL) in subsections 2.1.2.3.2.1 to 2.1.2.3.2.4 below.

Factors that affect state vector accuracy include:

- Errors in the navigational sensor system. For applications using ADS-B data, the measuring system is the aircraft/vehicle's navigation system. The error in the measured state vector will vary widely depending on the navigation source or sources used.
- Errors in the ADS-B reporting system. Additional error may be added due to the resolution of the reported state vector element (that is, the minimum increment that can be reported).
- Errors in the time of applicability. Because the A/V is moving, the reported state vector needs to meet latency requirements.
- Errors introduced by processing. Errors may also be introduced through the processing of the state vector data. These may be introduced, for example, from coordinate conversions and round-off errors in representing position and time values.

Aircraft/vehicle state vector information shall (R2.12) include the following elements:

1. Three-dimensional position
2. Three-dimensional velocity
3. Time of applicability of the three-dimensional position and velocity.

All non-stationary ADS-B subsystem installations shall (R2.13) provide dynamic state vector reporting.

2.1.2.2.1 Position

Position information shall (R2.14) be transmitted in a form that can be translated, without loss of accuracy and integrity, to latitude, longitude, and barometric altitude and geometric height.

All geometric position elements shall (R2.15) be referenced to the WGS-84 ellipsoid.

2.1.2.2.1.1 Horizontal Position

Horizontal latitude and longitude position shall (R2.16) be reported as a geometric position.

2.1.2.2.1.2 Altitude

Both barometric pressure altitude and geometric altitude (height above the WGS-84 ellipsoid) shall (R2.17) be reported, if available. Some applications may have to compensate if only one source is available. However, when an A/V is operating on the airport surface, the altitude is not required to be reported, provided that the A/V indicates that it is on the surface.

2.1.2.2.1.2.1 Pressure Altitude

Barometric pressure altitude is the reference for vertical separation within the NAS and ICAO airspace. Barometric pressure altitude shall (R2.18) be reported referenced to standard temperature and pressure.

2.1.2.2.1.2.2 Geometric Altitude

Geometric altitude is defined as the length of the line segment that extends from the current aircraft position to the surface of the earth's ellipsoid as defined by WGS-84 [7]. It is positive for aircraft positions above that surface, and negative for positions below the ellipsoid surface.

2.1.2.2.1.2.3 Altitude Range

Altitude shall (R2.19) be provided with a range from -1,000 ft up to +100,000 ft. For fixed or tethered objects, the altitude of the highest point should be reported.

2.1.2.2.2 Velocity Vector

The transmitting aircraft shall (R2.20) provide the following information:

- Horizontal Velocity Vector
- Vertical Rate

ADS-B geometric velocity information shall (R2.21) be referenced to WGS-84 [7].

2.1.2.2.2.1 Horizontal Velocity Vector

Horizontal velocity information shall (R2.xx) be transmitted in a form that can be translated, without loss of accuracy and integrity, to north-south and east-west velocity relative to the WGS-84 earth ellipsoid. Reported ranges shall (R2.22) be [0-250] knots on the surface and [0-4000] knots airborne.

2.1.2.2.2.2 Altitude Rate

Altitude Rate shall (R2.23) be designated as climbing or descending and shall be reported up to 32,000 feet per minute (fpm). Barometric altitude rate is defined as the current rate of change of barometric altitude. Likewise, geometric altitude rate is the rate of change of geometric altitude. << The following text will likely be deleted or changed: "For NAC values 10 and 11, geometric altitude rate shall (R2.24) be reported. For other NAC values, barometric altitude rate or inertially augmented barometric altitude rate shall (R2.25) be reported.">>

2.1.2.2.3 Heading

Heading indicates the orientation of the A/V and is described as an angle measured clockwise from true north or from magnetic north. (The heading reference direction is conveyed in the MS report.) If the heading of an A/V is available, it shall (R2.xx) be transmitted while that A/V is on the surface.

To promote ADS-B equipage by as many aircraft as possible, participants are not required to have a heading source available if their aircraft size code (section TBD) is 2 or less. However, ADS-B participants of aircraft size code 3 or above, shall (R2.xx) have a heading source available and shall (R2.xx) transmit messages to support the heading element of the SV report when those participants are on the surface.

Heading occurs not only in the SV report for participants on the airport surface, but also in the On Condition – Air Referenced Velocity (OC-ARV) report for airborne participants. If a transmitting ADS-B participant has heading available, it shall (R2.xx) provide heading in any messages it transmits to support OC-ARV reports.

2.1.2.3 Status Information

Status information is used to support ATS and A/V to A/V applications. Elements include:

- Capability Class Codes
- State Vector Integrity and Accuracy Codes
- Emergency/Priority Status (to support ATS applications)

Note: The information in this subsection is provided as a guidance to system designers and manufacturers. This information is in the process of evolving into final requirements.

2.1.2.3.1 Capability Class Codes

Capability class codes are used to indicate the capability of a participant to support engagement in specific operations. Known specific capability class codes are listed below. However, this is not an exhaustive set and provision should be made for future expansion of available class codes, including appropriate combinations thereof:

- CDTI based traffic display capability
- TCAS/ACAS installed and operational
- Equipage class of a transmitting ADS-B subsystem
- Capability of transmitting Air Referenced Velocity
- Capability of transmitting Target Altitude
- Capability of transmitting Target Heading or Target Track Angle

2.1.2.3.2 State Vector Integrity and Accuracy

The integrity and accuracy of the state vector navigation variables are characterized by Navigation Integrity Category (NIC), Navigation Accuracy Categories (NAC_P and NAC_V), and Surveillance Integrity Level (SIL).

2.1.2.3.2.1 Navigation Integrity Category

The Navigation Integrity Category (NIC) is reported so that surveillance applications may determine whether the reported position has an acceptable level of integrity for the intended use. The NIC parameter described in this subsection is intimately associated with the SIL (Surveillance Integrity Level) parameter described in subsection 2.1.2.3.2.4 below. The value of the NIC parameter specifies an integrity containment radius, R_C. The integrity containment radius is defined as the radius of a circle, centered on an A/V's reported horizontal position, which "is assured to contain" that A/V's true position. The SIL parameter (section 2.1.2.3.2.4) specifies what the words "is assured to contain" in the preceding sentence mean.

Note: "NIC" and "NAC_P" as used in the current version (DO-242A) of this MASPS replace the earlier term, "NUC_P", used in the first edition (DO-242) of this MASPS. [<<ref. to DO-242, dated February 19, 1998>>].

Table 2.1.2.3.2.1 defines the navigation integrity categories that transmitting ADS-B participants shall (R2.xxx) use to describe the integritycontainment radius, R_C, associated with the horizontal position of positional information in ADS-B messages from those participants.

Table 2.1.2.3.2.1: Navigation Integrity Categories (NIC)

NIC [Note 2]	**Horizontal Containment Radius, Rc**	**Comment**	**Notes**
0	$R_C \geq 37.04$ km (20 nmi)	No Integrity	
1	$R_C < 37.04$ km (20 nmi)	RNP-10 containment radius	
2	$R_C < 14.816$ km (8 nmi)	RNP-4 containment radius	[3]
3	$R_C < 7.408$ km (4 nmi)	RNP-2 containment radius	
4	$R_C < 3.704$ km (2 nmi)	RNP-1 containment radius	
5	$R_C < 1852$ m (1 nmi)	RNP-0.5 containment radius	
6	$R_C < 1111.2$ m (0.6 nmi)	RNP-0.3 containment radius	
7	$R_C < 370.4$ m (0.2 nmi)	RNP-0.1 containment radius	
8	$R_C < 185.2$ m (0.1 nmi)	RNP-0.05 containment radius	
9	$R_C < 75$ m	Future system	
10	$R_C < 25$ m	e.g., WAAS HPL	
11	$R_C < 7.5$ m	e.g., LAAS HPL	
12-15	Reserved for progressively tighter integrity containment radii.		

Notes for Table 2.1.2.3.2.1:

1. *NIC is reported by an aircraft because there will not be a uniform level of navigation equipage among all users. Although GNSS is intended to be the primary source of navigation data used to report ADS-B horizontal position, it is anticipated that during initial uses of ADS-B or during temporary GNSS outages an alternate source of navigation data may be used by the transmitting A/V for ADS-B position information. The integration of alternate navigation sources is a function that must be performed by a navigation set that is certified to use multiple sources, which then is responsible for supplying the corresponding containment integrity (i.e., HPL). It is important to point out that this is not a function that can be performed by the ADS-B equipment.*
2. *"NIC" in this column corresponds to "NUC_P" of Table 2-1(a) in the first version of this MASPS, DO-242, dated February 19, 1998.*
3. *The containment radius for NIC = 2 has been changed (from the corresponding radius for NUC_P = 2 in the first edition of this MASP) so as to correspond to the RNP-4 RNAV limit of DO-236A, rather than the RNP-5 limit of the earlier DO-236. This is because the RNP-5 number has been dropped from the ICAO standard RNP values.*

The coded representations of NIC should be such that:

(a) Equipment that conforms to the current version of this MASPS ("version 1" equipment) will recognize the equivalent NUC_P codes from the first edition of this MASPS, and

(b) Equipment that conforms to the initial, DO-242, edition of this MASPS ("version 0" equipment) will treat the coded representation of NIC coming from equipment that conforms to the current, DO-242A, version of this MASPS ("version 1" equipment) as if they were the corresponding "NUC_P" values from the first initial, DO-242, version of this MASPS [<<insert reference to DO-242>>].

2.1.2.3.2.2 Navigation Accuracy Category for Position (NAC_P)

The Navigation Accuracy Category for Position (NAC_P) is reported so that surveillance applications may determine whether the reported position has an acceptable level of accuracy for the intended use.

Note 1: "NIC" and "NAC_P" as used in this MASPS replace the earlier term, "NUC_P", used in the initial, DO-242, edition of this MASPS [<<ref. to DO-242, dated February 19, 1998>>].

Table 2.1.2.3.2.2 defines the navigation accuracy categories that shall (R2.xxx) be used to describe the accuracy of positional information in ADS-B messages from transmitting ADS-B participants.

Note 2: The Estimated Position Uncertainty (EPU) used in Table 2.1.2.3.2.2 is a 95% accuracy bound. The horizontal EPU (HEPU) is defined as the radius of a circle, centered on the reported position, such that the probability of the actual position being outside the circle is 0.05. Likewise, the vertical EPU (VEPU) is defined as a vertical position limit, such that the probability of the actual vertical position differing from the reported vertical position by more than that limit is 0.05.

Table 2.1.2.3.2.2: Navigation Accuracy Categories for Position (NAC_P).

NAC_P	95% Horizontal and Vertical Accuracy Bounds (HEPU and VEPU)	Comment
0	HEPU ≥ 18.52 km (10 nmi)	Unknown accuracy
1	HEPU < 18.52 km (10 nmi)	RNP-10 accuracy
2	HEPU < 7.408 km (4 nmi)	RNP-4 accuracy
3	HEPU < 3.704 km (2 nmi)	RNP-2 accuracy
4	HEPU < 1852 m (1nmi)	RNP-1 accuracy
5	HEPU < 926 m (0.5 nmi)	RNP-0.5 accuracy
6	HEPU <555.6 m (0.3 nmi)	RNP-0.3 accuracy
7	HEPU < 185.2 m (0.1 nmi)	RNP-0.1 accuracy
8	HEPU <92.6 m (0.05 nmi)	RNP-0.05 accuracy
9	HEPU < 30 m	e.g., GPS – SPS (SA off)
10	HEPU < 10 m and VEPU< 15 m	e.g., WAAS
11	HEPU < 3 m and VEPU < 4 m	e.g., LAAS
12-15	Reserved for progressively tighter HEPU and VEPU values	

2.1.2.3.2.3 Navigation Accuracy Category for Velocity (NAC_V)

The velocity accuracy category of the least accurate velocity component being supplied by the reporting A/V's source of velocity data shall (R2.27) be as indicated in Table 2.1.2.3.2.3.

Note: NAC_V is another name for the parameter that was called NUC_R in the initial (DO-242) version of this MASPS.

Table 2.1.2.3.2.3: Navigation Uncertainty Accuracy Categories for Velocity (NAC_V).

NAC_V	Horizontal Velocity Error (95%)	Vertical Velocity Error (95%)
0	Unknown or ≥ 10 m/s	Unknown or ≥ 50 feet per second
1	< 10 m/s	< 50 feet per second
2	< 3 m/s	< 15 feet per second
3	< 1 m/s	< 5 feet per second
4	< 0.3 m/s	< 1.5 feet per second

Notes to Table 2.1.2.3.2.3:

1. *When an inertial navigation system is used as the source of velocity information, error in velocity with respect to the earth (or to the WGS-84 ellipsoid used to represent the earth) is reflected in the NAC_V value.*
2. *When any component of velocity is flagged as not available the value of NAC_V will apply to the other components that are supplied.*

Commentary:

Navigation sources, such as GNSS and inertial, provide a direct measure of velocity which can be significantly better than that which could be obtained by position differences.

2.1.2.3.2.4 Surveillance Integrity Level (SIL)

The Surveillance Integrity Level (SIL) defines the probability of the integrity containment radius used in the NIC parameter (subsection 2.1.2.3.2.1above) being exceeded, without the possibility of exceeding that limit being detected aboard the A/V on which the transmitting ADS-B subsystem resides. The Surveillance Integrity Limit encoding shall (R2.xxx) be as indicated in Table 2.1.2.3.2.4.

Table 2.1.2.3.2.4: Surveillance Integrity Levels (SIL).

SIL	Probability of Unknowingly Exceeding the R_C Integrity Containment Radius	Comment
0	Unknown	Usable only by "Non-Interfering" Applications (No Hazard Level)
1	1×10^{-3} per flight hour or per operation	Usable by "Non-Essential" Applications (Minor Hazard Level)
2	1×10^{-5} per flight hour or per operation	Usable by "Essential" Applications (Major Hazard Level)
3	1×10^{-7} per flight hour or per operation	Usable by "Critical" Applications (Severe Major Hazard Level)

2.1.2.3.3 Emergency/Priority Status

The ADS-B system shall (R2.28) be capable of supporting broadcast of emergency and priority status. Status shall (R2.29) include the following:

- No emergency / Not reported
- General emergency
- Lifeguard/medical
- Minimum fuel
- No communications
- Unlawful interference

2.1.2.3.4 Short Term Intent

Several intent variables are being considered for broadcast by ADS-B. Short term intent information may include Selected Altitude, Target Altitude, Target Heading or Track , intent status, and/or other variables to be determined by ongoing studies.

Selected Altitude is an intended altitude that the pilot has selected using the Mode Control Panel (MCP) or Flight Control Unit (FCU). Often this is the altitude to which the aircraft has most recently been cleared by ATC.

Target Altitude is the altitude at which the altitude is expected next to change its vertical movement, according to whichever device (MCP/FCU, FMS, etc.) is currently controlling the aircraft. This may be the altitude of the next waypoint in a flight plan that has been entered into the FMS, or the top-of-climb or bottom-of-descent altitude at which the aircraft will level off.

Note: *In Mode S transponders equipped for Downlink of Aircraft Parameters (DAPs), it is expected that Selected Altitude and Target Altitude may be obtainable by a external interrogator (e.g., ground SSR or airborne TCAS/ACAS) that interrogates the transponder for the contents of its GICB register number 20 {hex}.*

Target Heading/Track is the anticipated direction for horizontal turn completion, or the intended heading or ground track angle during a constant flight leg segment.

Intent status is a binary flag for onboard lateral compliance and a binary flag for onboard vertical compliance, indicating whether the current path is consistent with the broadcast intent variables described above.

2.1.2.3.5 Trajectory Change Intent (Current and Future)

Track extrapolations based on the use of intent data alone are increasingly inaccurate as look-ahead times are increased. The state vector can be augmented with trajectory change points (i.e., intent information) for applications on the receiving A/V or ATS to:

a) support stable separation predictions for long look-ahead times, and in monitoring required operational separations and

b) re-plan flight paths when necessary to resolve detected conflicts (deconfliction) while minimizing deviations from planned flight trajectories.

The ADS-B system shall (R2.30) provide the capability to exchange Trajectory Change Point (TCP) and Trajectory Change Point + 1 (TCP+1) data defined below. ADS-B transmissions shall (r2.31) indicate the ability of the transmitting participant to engage in path monitoring and/or de-confliction operations. The transmitting A/V shall (R2.32) also indicate its capability to use intent information received from other participants.

For certain pairwise operations, an addressed crosslink may be used external to the ADS-B system.

2.1.2.3.5.1 Current Trajectory Change Point (TCP)

The TCP from the transmitting aircraft is the point in three-dimensional space where the current operational trajectory is planned to change, and estimated remaining flight time to that point. A TCP transmission indicates that the aircraft intends to fly directly, via a great circle route, to that point. The TCP is defined as a four-element vector consisting of the following:

- Latitude (WGS-84)
- Longitude (WGS-84)
- Altitude (pressure altitude or flight level)
- Time to go (TTG) to the indicated point in space

The TCP required received update rate may be lower than for the state vector. The rate shall (R2.33) be sufficient to ensure continuous positive assessment by the receiving aircraft at least 2 minutes (5 minutes within the range limitations specified in Table 2-3) prior to reaching closes point of approach for class A2 (A3) equipage. In the event of an immediate trajectory change generated via the RNav, new TCP information should be issued immediately.

The augmentation data should be provided as data transmitted indicating planned changes in trajectory. These indications should be provided as TCP information and TCP+1 information described below. This data is required only from participants intending operations based on some level of cooperative conflict management. The TCP and TCP+1 should be used to convey information operationally significant to separation and conflict management. Points constructed by RNav equipment to generate curvilinear paths (e.g., curved transitions between flight legs) should not be conveyed as TCP information.

System designs should be flexible enough to support parameters that might not be available from all ADS-B participating A/Vs. Information acquisition of intent information is provided in Appendix L.

2.1.2.3.5.2 Next Trajectory Change Point (TCP+1)

De-confliction is most efficient when adjustments to the flight path can be minimized. Knowledge of planned changes to the current path is needed to support the conflict management tools for stable operational re-planning required due to any conflict that may be predicted.

For the de-confliction capability, additional augmenting information should be provided to determine any change in horizontal and/or vertical flight path planned. The aircraft planning the change shall (R2.34) issue the TCP+1 information at least 5 minutes prior to commencing the trajectory change associated with the TCP. The TCP+1 data to be supplied should provide the target or predicted altitude, the target horizontal coordinates and the estimated time remaining from the time of generation of the message to the estimated time to arrive at TCP+1. Upon initiation of the flight path change at TCP, the TCP+1 should increment to become the new TCP. TCP+1 information shall (R2.35) be provided until commencing the change maneuver. The TCP+1 required transmission rate shall (R2.36) be the same as that of the TCP.

Notes:

1. *TCP and TCP+1 data are provided by broadcast media to supply real-time, event-related data to proximate air and ground systems involved in advanced air operations requiring real time intent detail. Details of more complete flight plan or detailed procedures are conveyed, when required, via addressed datalink media.*
2. *No TCP is needed for speed changes along a trajectory. The data indicating the time to go for TCP and TCP+1 should include any results of planned or predicted changes. For RNav equipment capable of such predictions or scheduling, the time data should include the impacts. Less capable equipment should provide the best estimate available. Air or Ground systems receiving the TCP/TCP+1 data should be*

capable of applying these data as appropriate to their respective applications in conflict management, sequencing, spacing or conformance.

3. *TCP and TCP+1 data are envisioned in current planning future procedures in the terminal area and transitions between en route flight regimes to enhance sequencing in arrival and departure. These data are intended for applications by both air and ground systems. The ADS-B system will enable the delivery of TCP and/or TCP+1 data when required by the procedures supported by the RNav onboard the transmitting participant. Receiving participants would use the transmitted capability codes to determine pair-wise compatibility with their respective applications.*

   For example, at shorter ranges, a pair of points (TCP and TCP+1) could be issued in conjunction with Terminal Maneuvering Area metering operations and/or when maneuvering to join or depart published procedures.

4. *Lateral TCPs are fly-by points unless indicated to be fly-over. TCP and tCP+1 points are intended to convey trajectory target and trajectory change only. Accordingly, they are not necessarily RNav flight plan waypoints. They must be represented only in binary data form. Example TCPs are top of descent, reach climb altitude or intercept points used to capture procedures or join the flight plan.*

5. *Under some common operational sequences an aircraft may be manually departing or returning to an RNav flight plan. An example case would result from a period of vectored operation by ATS. In such cases the application should determine when to assume the intent is "direct-to" or if the aircraft is operating with a different intent.*

2.1.2.4 Other Information

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3.2.3 Equipage Classifications

As illustrated above, ADS-B equipment must be integrated into platform architectures according to platform characteristics, capabilities desired and operational objectives for the overall implementation. The technical requirements of this MASPS have been derived from consolidation of the scenarios presented in Section 2 within the context of the use of the <<more text, not copied here>>.

3.2.3.1 Interactive Aircraft/Vehicle ADS-B Subsystems (Class A)

Functional capabilities of interactive aircraft/vehicle subsystems are indicated in the context diagram of Figure 3-4. These subsystems accept own-platform source data, exchange appropriate ADS-B messages with other interactive ADS-B System participants, and assemble ADS-B reports supporting own-platform applications. Such interactive aircraft subsystems, termed Class A subsystems, are further defined by equipage classification according to the provided user capability. The following types of Class A subsystems are defined (Table 3-1):

- Class A0: Supports minimum interactive capability for participants. Broadcast ADS-B messages are based upon own-platform source data. ADS-B messages received from other aircraft support generation of ADS-B reports which are used by on-board applications (e.g., CDTI for aiding viusal acquisition of other-aircraft tracks by the own-aircraft's air crew). This equipage class may also support interactive ground vehicle needs on the airport surface.
- Class A1: Supports all class A0 functionality and additionally supports ADS-B conflict avoidance. Class A1 is intended for operation in IFR designated airspace.
- Class A2: Supports all class A1 functionality and additionally provides extended range and information processing to support optimized separation applications. This service requires the broadcast and receipt of trajectory change point data (TCP).
- Class A3: Supports all class A2 functionality and additionally supports flight path deconfliction. Class A3 subsystems support longer look-ahead times with longer operational ranges than class A2. Class A3 has the ability to broadcast and receive strategic planning information such as future trajectory change point data (TCP+1).

Table 3-1. Subsystem Classes and Their Features.

Class	Subsystem	Capability	Features	Comments
Interactive Aircraft/Vehicle Participant Subsysesm (Class A)				
A0	Minimum Interactive Aircraft/Vehicle	Aid to Visual Acquisition	Lower Tx power and less sensitive Rx than Class A1 permitted	Minimum Interactive capability with CDTI.
A1	Basic Interactive Aircraft	A0 plus Conflict Avoidance	Standard Tx and Rx	Provides ADS-B based conflict avoidance and interface to current TCAS surveillance algorithms/display.
A2	Enhanced Interactive Aircraft	A1 plus Separation Assurance and Sequencing	Standars Tx power and more sensitive Rx. Interface with avionics source required for TCP data.	Baseline for separation management employing intent information.
A3	Extended Interactive Aircraft	A2 plus Flight Path Deconfliction Planning	Higher Tx power and more sensitive Rx. Interface with avionics source required for TCP and TCP+1 data.	Extends planning horizon for strategis separation emplying intent information.
Broadcast-Only Participant Subsystems (Class B)				
B1	Aircraft Broadcast Only	Supports visual acquisition and conflict avoidance for other participants	Tx power may be matched to coverage needs. NAV input required.	Enables aircraft to be seen by Class A and Class C users.
B2	Ground Vehicle Broadcast Only	Supports visual acquisition and conflict avoidance on the airport surface	Tx power matched to surface coverage needs. High accuracy NAV input required.	Enables vehicle to be seen by Class A and Class C users.
B3	Fixed Obstruction	Supports visual acquisition and conflict avoidance	Fixed coordinates. No NAV input required. Collocation with obstruction not required with appropriate broadcast coverage.	Enables NAV hazard to be detected by Class A users.
Ground Receive Subsystems (Class C)				
C1	ATS En Route and Terminal Area Operations	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	En route coverage out to 200 nmi. Terminal coverage out to 60 nmi.
C2	ATS Parallel Runway and Surface Operation	Supports ATS cooperative surveillance	Requires ATS certification and interface to ATS sensor fusion system.	Approach coverage out to 10 nmi. Surface coverage out to 5 nmi.
C3	Flight Following Surveillance	Supports private user operations planning and flight following	Does not require ATS interface. Certification requirements determined by user application.	Coverage determined by application.

3.2.3.2 Broadcast-Only Subsystems (Class B)

Some ADS-B system participants may not need to be provided information from other participants but do need to broadcast their state vector and associated data. Class B subsystems meet the needs of these participants. Class B subsystems are defined as follows (Table 3-1):

- Class B1: Aircraft broadcast-only subsystem, as shown in Figure 3-3. Class B1 subsystems require an interface with own-platform navigation systems. Two types of equipage, corresponding to equivalent transmit powers and information capabilities as those of class A0 and A1, are permitted within this class. Use of the lower power alternative is determined by the same aircraft operational limits as those given for class A0.

- Class B2: Ground vehicle broadcast-only ADS-B subsystem. Class B2 subsystems require a high-accuracy source of navigation data and a nominal 5 nmi effective broadcast range. Surface vehicles qualifying or ADS-B equipage are limited those that operate within the surface movement area.
- Class B3: Fixed obstacle broadcast-only ADS-B subsystem. Obstacle coordinates may be obtained from available survey data. Collocation of the transmitting antenna with the obstruction is not required as long as broadcast coverage requirements are met. Fixed obstacles qualifying for ADS-B are structures and obstructions identified by ATS authorities as a safety hazard.

3.2.3.3 Ground Receive-Only Subsystems (Class C)

Surveillance state vector reports, mode-status reports, and on-condition reports are available from ADS-B system participants within the coverage domain of ground ADS-B receive-only, or Class C subsystems. The following Class C subsystems are defined (Table 3-1):

- Class C1: Ground ATS receive-only ADS-B subsystems for en route and terminal area applications. Class C1 subsystems should meet continuity and availability requirements determined by the ATS provider.
- Class C2: Ground ATS Receive-Only ADS-B Ground ATS receive-only ADS-B subsystems applications. Class C2 subsystems have more stringent accuracy and latency requirements than Class C1 systems. Class C2 systems may be required, depending upon the ADS-B System design, to recognize and process additional ADS-B message formats not processed by Class C1 subsystems.
- Class C3: Flight following surveillance is available from this equipage class for use by private operations planning groups or for provision of flight following and SAR.

3.3 System Requirements

3.3.1

3.3.2

3.3.3 ADS-B Data Exchange Requirements

3.3.3.1 Report Accuracy, Update Period, and Acquisition Range

Report accuracy, update period and acquisition range requirements are …

3.4 ADS-B Report Definitions

3.4.1 Report Assembly Design Considerations

3.4.2 ADS-B Message Exchange Technology Considerations in Report Assembly

3.4.3 Specific ADS-B Report Definitions

3.4.3.1 State Vector Report

The state vector (SV) report contains information about an aircraft or vehicle's current kinematic state. (Measures of the state vector quality are contained in the Mode Status Report, section 3.4.3.2 below.) Specific requirements for a transmitting participant to supply data for this report, or for a receiving participant to assemble this report from messages it receives from transmitting participants, will vary according to the intended capability of each participant. Paragraph 0 defines the required capabilities for each Subsystem Class defined in Section 3.2.2. Contents of the state vector are summarized in Table 3-5. Required update rates for this report, described by operational capability and operating range, are given in Section 3.3.3.

The surveillance SV report for each acquired participant contains the participant address for correlation purposes. Geometric based state vector information is referenced to the WGS-84 ellipsoid and consists of latitude, longitude, height above the ellipsoid, horizontal velocity, and altitude rate. Other state vector information includes pressure altitude, pressure altitude rate, and the heading of participants on the surface.

Note: Airspeed and heading for airborne participants are reported in the Air Referenced Velocity report, which is one of the On Condition reports. See section ??? below.

Pressure altitude, which is currently reported by aircraft in SSR Mode C and Mode S, will also be transmitted in ADS-B messages and reported to client applications in SV reports. The pressure altitude reported (SV element 8a) shall (R3.34) be derived from the same source as the pressure altitude reported in Mode C and Mode S for aircraft with both transponder and ADS-B.

Time-critical state vector elements are those indicated by bullets in the "Time-Critical SV Elements" column of Table 3.4.3.1. For systems utilizing segmented messages for SV data, time-critical state vector elements not updated in the current received message shall (R3.35) be estimated when the report is updated; otherwise SV elements shall (R3.35) be updated as new data is received.

State vector elements indicated by "R" in the "required from surface participants" column of Table 3-5 shall (R3.xxx) be transmitted by ADS-B participants that indicate that they are on the surface. Likewise, SV elements indicated by "R" in the "required from airborne participants" column shall (R3.xxx) be transmitted by ADS-B participants that do not indicate that they are on the surface. If a transmitting ADS-B participant does transmit the state vector elements indicated by "O" (for optional) in these columns, then it shall (R3.xxx) indicate that is transmitting those optional elements in the appropriate subfield of the messages that it transmits to support the MS report.

The time of applicability relative to local system time shall (R3.37) be updated with each State Vector report update. For other elements of the SV report, the report assembly function shall (R3.38) either provide updates when data is received or indicate "no data available" if no data are received in the preceding 10 second period.

The "Report Mode" SV element provides a positive indication when SV acquisition is complete and all applicable data sets and modal capabilities have been determined for the participant or that a default condition is determined by the Report Assembly function.

Table 3-5. State Vector Report Elements.

	SV Elem. #	Contents	[Notes]	Time-Critical SV Elements	Required from airborne participants	Required from surface participants	Minimum Equipage Level Which Must Transmit This Element	Reference Section
ID	1	Participant Address			**R**	**R**	A0	2.1.2.1.2
Geometric Position	2a	Latitude (WGS-84)		•	**R**	**R**	A0	2.1.2.3.1
	2b	Longitude (WGS-84)		•	**R**	**R**	A0	
	2c	Horizontal Position Valid		•	**R**	**R**	A0	
	3a	Geometric Altitude		•	**R**	N	A0	2.1.2.2.1.2
	3b	Geometric Altitude Valid		•	**R**	N	A0	
Geometric Velocity	4a	North Velocity while airborne	[1]	•	**R**	N	A0	2.1.2.2.2.1
	4b	East Velocity while airborne	[1]	•	**R**	N	A0	
	4c	Airborne Horizontal Velocity Valid	[1]	•	**R**	N	A0	
	5a	Ground Speed while on the surface		•	N	**R**	A0	2.1.2.2.2.1
	5b	Ground Speed (on the surface) Valid		•	N	**R**	A0	
Hdg	6a	Heading while on the Surface	[2, 3]	•	N	**R**	A0	2.1.2.2.3
	6b	Heading Valid	[3]	•	N	**R**	A0	
Baro Altitude	7a	Barometric Pressure Altitude		•	**R**	N	A0	2.1.2.2.1.2
	7b	Pressure Altitude Valid		•	**R**	N	A0	
Vertical Rate	8a	Vertical Rate (Baro/Geo)	[1, 2]	•	**R**	N	A0	2.1.2.2.2.2
	8b	Vertical Rate Valid	[1]	•	**R**	N	A0	
	8c	Alternate Type Vertical Rate (Geo/Baro)		•	O	N	-	2.1.2.2.2.2
	8d	Alternate Type Vertical Rate Valid		•	O	N	-	
TOA	9	Time Of Applicability – Time-Critical Data		•	**R**	**R**	A0	2.1.1.4
Report Mode	10	Report Mode (Report Assembly Function Mode For This Target: Acquisition, Track, Or Default)			**R**	**R**	A0	

Notes for Table 3-5:

[1] *SV elements marked "O" for "optional," if provided at all, need not be transmitted at the same update rate as elements marked "R" for "required." Whether or not a participant is transmitting an optional SV element shall be indicated in the "SV Report Modes" element of the MS report.*

[2] *Data type (True vs. Magnetic for heading, Barometric vs Geometric for vertical rate) is provided in the Mode Status Report.*

[3] *An ADS-B participant on the airport surface may transmit track angle instead of heading, but only if it does not have a source of heading information. A surface participant that transmits track angle rather than heading should be sure to clear the SV element #6b, "heading valid," when the A/V is moving so slowly that the track angle does not meet the required accuracy for heading.*

3.4.3.2 Mode Status Reports

The mode-status (MS) report contains current operational information about the transmitting participant. This information includes participant type, mode specific parameters, status data needed for certain pairwise operations, and assessments of the integrity and accuracy of position and velocity elements of the SV report. These elements require lower update rates than the SV report. Specific requirements for a participant to supply data for and/or generate this report subgroup will vary according to the equipage class of each participant. Paragraph 0 defines the required capabilities for each Equipage Class defined in Section 3.2.2. Classes define the level of MS information to be exchanged from the source participant to support correct classification onboard the user system.

The Mode-Status report for each acquired participant contains the unique participant address for correlation purposes, static and operational mode information and Time of Applicability. Contents of the Mode-Status report are summarized in Table 3.4.3.2.

The static and operational mode data includes the following information:

- Capability Class Codes – used to indicate the capabilities of a transmitting ADS-B participant.
- Operational Mode Specific Parameters – e.g., Speed target, Mag/True track, IAS/TAS.

For each participant the Mode-status report shall (R3.41) be updated and made available to ADS-B applications any time a new message containing all, or a portion of, its component information is accepted from that participant. For all applications other than Aid to Visual Acquisition the required MS report must be available to qualify for ADS-B operations.

The time of applicability relative to local system time shall (R3.42) be updated with every Mode-status report update. For all elements of MS report the assembly function shall (R3.43) provide update when received or indicate "no data available" is none is received in the preceding 10 second period.

Table 3.4.3.2: Mode-Status (MS) Report Definition.

	MS Elem. #	Contents [Notes]	Minimum Equipage Level Which Must Transmit This MS Report Element	Reference Section
ID	1	Participant Address	A0	2.1.2.1.2
	2	Call sign (up to 8 alpha-numeric characters)	A0	2.1.2.1.1
	3	Participant Category	A0	2.1.2.1.3
	4	Surveillance Support Code (Normal or Default) [2]	A0	
	5	Emergency/Priority Status	A0	2.1.2.3.3
	6	Capability Class Codes	A0	2.1.2.3.1
		6a: CDTI display enabled	A0	
		6b: TCAS enabled	A0	
		6c: Equipage class of transmitting participant	A0	
		6d: Capability of transmitting Target Altitude	A2	
		6e: Capability of transmitting Target Heading or Target Track Angle	A2	
Integrity and Accuracy	7a	NIC, Navigation Integrity Category	A0	2.1.2.3.2.1
	7b	NAC_P, Navigation Accuracy Category - position	A0	2.1.2.3.2.2
	7c	NAC_V, Navigation Accuracy Category - velocity	A0	2.1.2.3.2.3
	7d	SIL, Surveillance Integrity Level	A0	2.1.2.3.2.4
	8	Operational Mode Specific Data		
	9	Flight Mode Specific Data [3]		
TOA	1011	Time of Applicability	A0	2.1.1.4

Notes for Table 3.4.3.2:

1. *"Normal" means that for the stated capability class codes (field 6), all data are reliable. "Default" means that the transmitting ADS-B participant advises that some transmitted data are not reliable or unavailable.*

2. *Flight mode specific data will be defined in a lower level of documentation and be included through revision to the MASPS. Examples are: touchdown speed and pair-wise operational capabilities.*

3.4.3.3 On-Condition Reports

3.4.3.3.1 On Condition – Air Referenced Velocity (OC – ARV) Report

The On Condition – Air Referenced Velocity (OC – ARV) report contains velocity information that is not required about all airborne ADS-B transmitting participants, and that may not be required at the same update rate as the position and velocity elements in the SV report.

3.4.3.3.2 On Condition - TCP (OC – TCP) Report

3.4.3.3.3 On Condition - TCP+1 (OC – TCP+1) Report